

ADDRESSING CONTROL OF HAZARDOUS ENERGY REQUIREMENTS IN A LASER SAFETY PROGRAM¹

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Abstract

OSHA regulation 29CFR1910.147 specifies control of hazardous energy requirements for “the servicing and maintenance of machines and equipment in which the unexpected energization or start up of the machines or equipment, or release of stored energy could cause injury to employees.” Class 3B and Class 4 laser beams must be considered hazardous energy sources because of the potential for serious eye injury; careful consideration is therefore needed to safely de-energize these lasers. This paper discusses and evaluates control of hazardous energy principles in this OSHA regulation, in ANSI Z136.1 “Safe Use of Lasers,” and in ANSI Z244.1 “Control of Hazardous Energy, Lockout/Tagout and Alternative Methods.” Recommendations are made for updating and improving CoHE (control of hazardous energy) requirements in these standards for their applicability to safe laser operations.

1. Introduction

Laser injuries can occur when laser hazards are mistakenly believed to be disabled [1], as well as during activities when these hazards are known to be enabled. This paper focuses on the former category of injuries, which can be prevented if a proper approach to CoHE is used! CoHE controls are described in ANSI Z136.1, but they are not explicitly identified as such and key CoHE concepts such as *zero energy verification* are not mentioned. Laser safety programs need to ensure that sufficient CoHE controls are used when disabling laser hazards, and should utilize the OSHA CoHE regulation 1910.147 and the ANSI CoHE standard Z244.1 for this, in addition to the ANSI laser safety standard Z136.1. Please note that the context for CoHE used in this paper is broader than that used in OSHA 1910.147, which is focused on

using lockout/tagout (LOTO). Here, CoHE describes all controls used to safely de-energize equipment to prevent injuries that might occur from the mistaken belief a hazardous energy source is disabled.

The laser community typically considers that the OSHA CoHE regulation does not apply to laser hazards, citing one or more of the following reasons:

- the regulation only applies to electrical hazards
- the laser system is in normal operation mode
- the laser’s activation warning system prevents unexpected hazardous laser radiation
- the laser hazard can be disabled by removing a Master Key
- the engineered laser safety system can be used instead of LOTO because it provides an effective alternative energy control system that can be used as machine guarding (or as part of an administrative lockout)
- the OSHA-LIA alliance [2] acknowledges that ANSI Z136.1 addresses all laser safety requirements. (Note that the focus of this alliance is on training, education, outreach and communication to prevent hazardous laser exposures. It does not indicate that the OSHA 1910.147 regulation does not apply to laser hazards.)

Often these cited reasons are incorrect and inadequate consideration is given to achieving effective controls for disabling laser hazards.

2. OSHA CoHE Regulation 1910.147

The OSHA CoHE regulation [3] establishes control measure requirements for hazardous energy during maintenance and service work. It applies to “any source of electrical, mechanical, hydraulic, pneumatic, chemical, thermal, or other energy.” Operation of equipment, including laser systems, can be considered to fall into one of three modes: normal operation, maintenance, and service. In industry, normal

¹ Presented at the [2011 International Laser Safety Conference](#), San Jose, CA; and at the [2011 International Technical Safety Forum](#), SLAC National Accelerator Laboratory, Stanford, CA.

operation generally means “production” mode where the configuration of equipment is stable. Maintenance means routine work is performed to maintain performance specifications for equipment. Service means that infrequent repair work is being carried out. Some examples of maintenance and service work are cited, such as “constructing, installing, setting up, adjusting, inspecting, and modifying machines or equipment.” In an R&D laser lab, however, some of these examples are typically considered part of normal operations when beam paths are aligned or modified or damaged optics are replaced.

The only means discussed in the OSHA regulation for achieving CoHE during maintenance and service is LOTO, and the regulation is focused on when and how to apply LOTO. There are four key principles or ingredients described:

- **Energy isolation devices.** Equipment must include such devices, to which LOTO can be applied.
- **Zero energy verification.** This is required after de-energizing equipment, and prior to commencing maintenance or service work.
- **Personal control.** Each individual must apply their own lock.
- **Equipment lockout procedure (ELP).** In general a written lockout procedure is needed.

The regulation does not cover normal operations, unless a safety device is removed or bypassed or an employee is required to place any part of their body into a danger zone. Minor service and maintenance activities performed during normal operations do not require LOTO if they are “routine, repetitive and integral to the use of the equipment for production.” When LOTO is not used to protect against accidental startup of a hazardous energy source in these circumstances, OSHA requires alternative control methods that utilize machine guards as described in 29CFR1910 Subpart O [4]. OSHA’s general requirements for machine guards are much less stringent than OSHA LOTO requirements – 29CFR1910.212 merely states that “One or more methods of machine guarding shall be provided to protect the operator and other employees in the machine area from hazards ... Examples of guarding methods are barrier guards, two-hand tripping devices, electronic safety devices, etc.”

There are some exemptions to the applicability of LOTO requirements in this OSHA regulation. These include:

- cord & plug connected electric equipment, if the plug is under exclusive control of an authorized employee performing the work, and

- at Department of Energy facilities, DOE rule 10CFR851 [5] provides an exemption for applicability to radiological hazards and nuclear explosives operations to the extent that they are regulated by 10 CFR Parts 20, 820, 830 or 835.

The focus of OSHA 1910.147 is on when and how to apply LOTO. In fact, it almost makes CoHE synonymous with LOTO. LOTO has deficiencies, however, which should be addressed. Some of these deficiencies, in particular with regard to laser use, include:

- When LOTO is applied, strict guidelines govern how to apply it. One should avoid situations where bad LOTO practice may arise (e.g., if LOTO needs to be applied and removed frequently, or if many workers on a given system need to apply locks).
- Zero energy verification may not be practical to be performed by certain workers.
- LOTO of complex systems involves a highly administrative procedure, which is prone to mistakes by personnel practicing it.

3. ANSI CoHE Standard Z244.1

This standard is titled “Control of Hazardous Energy – Lockout/Tagout and Alternative Methods” [6]. It predates the OSHA CoHE(LOTO) regulation and its original title in 1982 was “Personnel Protection – Lockout/Tagout of Energy Sources – Minimum Safety Requirements.” Z244.1 was most recently updated in 2003 and its title was changed then, with the following note given in the standard: “The title of the standard was modified to recognize the broader universe of hazardous energy control. The standard now more effectively addresses the need for greater flexibility through the use of alternative methods based on risk assessment and application of the hazard control hierarchy.”

The ANSI CoHE standard provides guidance for using alternative methods “for tasks that are routine, repetitive, and integral to the production process, or where traditional lockout/tagout prohibits the completion of those tasks.” These alternative controls use the following hierarchy:

- i. eliminate hazard,
- ii. engineering controls,
- iii. warnings and alerting personnel,
- iv. administrative procedures, and
- v. personal protective equipment (PPE).

Risk assessment is performed to evaluate the probability of exposure and severity of potential injury. The **controls hierarchy** is used and the assessment

evaluates the effectiveness of the controls, determining the integrity and extent of alternative controls needed.

Neither Z244.1 nor OSHA 1910.147 specifically address or mention lasers. Forty-six interpretations for the 1910.147 regulation are posted on the OSHA CoHE website [7], but none concern lasers. Interpretation 17, however, discusses the relation of 1910.147 with ANSI Z244.1. The OSHA CoHE webpage [8] and a 2008 OSHA directive CPL 02-00-147 [9] give further comments. They remark that Z244.1 is not an OSHA regulation and note that compliance with its requirements does not ensure compliance with 1910.147. CPL 02-00-147 makes the following statements:

- "The ANSI standard appears to sanction practices that may provide less employee protection than that provided by compliance with the relevant OSHA provisions. For example, the consensus standard employs a decision matrix that allows employers to use alternative protective methods in situations where OSHA standards require the implementation of machine guarding or lockout/tagout."
- "When an OSHA standard prescribes a practice, design, or method that provides a requisite level of employee protection, employers may not adopt an alternative approach that provides a lesser level of employee protection."

4. Laser Safety Standards for Laser Users and Manufacturers

The ANSI Z136.1 standard for *Safe Use of Lasers* [10] provides little discussion or guidance on compliance with the OSHA 1910.147 regulation. LOTO is mentioned only three times in the standard:

- Section 4.3.4 discusses key control and requirements for a "Master Switch" for Class 3B and Class 4 lasers, stating that "all energy sources associated with Class 3B or Class 4 lasers shall be designed to permit lockout/tagout procedures required by OSHA." This section also states that "during periods of prolonged non-use, the master switch should be left in a disabled condition (key removed or equivalent)," implying that key removal is sufficient to disable the laser hazard.
- Section 4.5.2.2 discusses fiber optic transmission for Class 3B and Class 4 radiation, and states "appropriate procedures should be instituted to prevent inadvertent personnel exposure from an unterminated or severed fiber, such as lockout/tagout requirements at the source."
- Appendix F Section F1.1.5 discusses electrical safety associated with laser systems, stating

"Where applicable, the user should comply with provisions of OSHA Standards for Electrical Safety-Related Work Practices (29 CFR 1910 Subpart S) and the Control of Hazardous Energy."

Federal Regulation 21CFR1040.10, *Performance standards for laser products* [11], specifies requirements for laser manufacturers. No explicit discussion of LOTO requirements is given, but the regulation does require CoHE features for Class 3B and Class 4 lasers, including:

- Master Key requirement. The Master Key shall be removable and the laser shall not be operable when the key is removed.
- Activation warning system. An audible or visual laser emission indicator is required, which is active prior to laser emission to allow actions to avoid exposure.

ANSI Z136.1 also has requirements that address CoHE principles with "alternative controls", including:

- Master Key requirements as described in Section 4.3.4, though this was weakened in the 2007 revision to change requirement from a "shall" to "should" for Class 4 lasers.
- Activation warning system requirements as described in Section 4.3.9.4. These include a mandatory visual or audible warning during startup, but no longer include an emission delay requirement. (An emission delay, similar to that described in CDRH 1040.10, was required in the 1993 version of Z136.1; this is not present in the 2000 and 2007 versions.)
- Laser Controlled Area (LCA) requirements as described in Section 4.3.10 to protect non-laser personnel from unexpected exposure to laser radiation and to notify laser personnel of the current state of laser hazards in the LCA.
- Written Standard Operating Procedure (SOP) document as described in Sections 4.4.1 and 4.4.5. The SOP can be considered as similar to the ELP described in Section 2 above and should describe how the Class 3B or Class 4 laser can be put in a safe state such that laser eyewear protection (LEP) is not needed.

5. Recommendations for updating CoHE Requirements in OSHA 1910.147 and ANSI Z136.1

CoHE should be defined as "Control measures used to protect workers from the unexpected presence of hazardous energy." This would apply to all modes of operation: normal, maintenance and service.

CoHE controls need to be broader than LOTO and should encompass 3 different approaches:

- i. LOTO, modelled after the approach in OSHA 1910.147,
- ii. Alternative controls, modelled after the description in ANSI Z244.1 (for laser work this would incorporate some of the controls described in ANSI Z136.1 such as a Master Key, activation warnings and LCA requirements), and
- iii. Administrative lockout or configuration control, where an equipment custodian or a supervisor locks out or disables a hazard but individual workers do not apply their own locks.

CoHE requirements should address six key CoHE principles (adapted from the four mentioned in Section 2 pertaining to OSHA 1910.147 and two more noted in Section 3 from ANSI Z244.1):

- i. **Hazard analysis.** This evaluates the probability for a hazardous exposure and the potential consequences, both with and without controls mitigation.
- ii. **Controls hierarchy.** A combination of controls can be used, but they should follow this priority: eliminate the hazard, engineering controls, visual and audible warnings to alert personnel, written administrative procedures, and PPE.
- iii. **Energy isolation devices and machine guards.** Equipment must include such devices, which can be used as an alternative control or to which LOTO can be applied. All equipment must have at least one identified energy isolation device to which LOTO can be applied.
- iv. **Zero energy verification.** This is required after de-energizing equipment, and prior to commencing maintenance or service work or removing PPE.
- v. **Personal control.** Each worker must have adequate training, knowledge and control over hazardous energy for their own safety, commensurate with the hazard analysis.
- vi. **Administrative procedure.** In general, a written procedure is needed. (For LOTO, this would be an ELP. For laser work, CoHE procedures could be included in the SOP document.)

6. Additional Specific Recommendations for updating ANSI Z136.1

This standard should be updated to include the following:

- describe 2 categories of hazards:
 - i. when hazardous laser beams are accessible (LEP normally required as an additional barrier to engineering and administrative controls)
 - ii. when hazardous laser beams are inaccessible or disabled and CoHE practices are followed to ensure the hazards are disabled (LEP not required)
- define and discuss CoHE and include description of the following CoHE principles: energy isolation devices and machine guards, zero energy verification, personal control, written procedures, hazard assessment and controls hierarchy.
- address compliance with the OSHA CoHE regulation.
- identify requirements that address CoHE with “alternative controls” – e.g., Master Key, activation warning system, safety shutters, LCA and SOP requirements.
- include an emission delay requirement in activation warnings for Class 3B and Class 4 lasers (at least a *should* requirement is needed).
- Include zero energy verification as a required administrative procedure when disabling Class 3B or Class 4 lasers, and prior to removing LEP. (This key CoHE principle is currently not mentioned in the standard!)
- Include in Section 4.1 as one of the common conditions that lead to laser accidents, the following: when a person mistakenly thinks the laser beam is disabled.

7. Addressing CoHE in a Laser Safety Program

The focus of CoHE in a laser safety program should be to protect workers from the unexpected presence of hazardous laser energy when the laser hazard is believed to be disabled, independent of whether the operation mode is normal, maintenance or service.

The approach given in the recommendations in Sections 5 and 6 should be followed, which includes addressing the six CoHE principles listed. Controls used must provide effective protection for all workers ***and*** must also address compliance with the OSHA CoHE requirements in 1910.147. Addressing CoHE principles includes:

- SOP documentation. Identify machine guards and energy isolation devices used, and describe procedures used to disable a laser hazard and perform zero energy verification (e.g., when switching from Class 4 operation to Laser Off or Class 1).
- Zero-energy verification. When switching to Laser Off or Class 1 operation, perform a zero-energy verification (e.g., by verifying power supply status, safety shutter position, or an appropriate laser energy diagnostic).
- Machine guards. Examples include Master Key, safety shutters, activation warning system, and the LCA.
- Energy isolation devices. Examples may include lockable safety shutters, circuit breakers and enclosures.
- Personal control over hazardous energy. Workers need adequate training in machine guards and energy isolation devices used and must follow SOP requirements. Good On-the-Job Training (OJT) is critical and must include: key safety devices, zero energy verification, and configuration control.
- Hazard assessment and controls hierarchy. The hazard assessment needs to ensure that the controls will effectively minimize the risk of a hazardous exposure. Priority needs to be given to eliminating hazards and using engineering controls that have sufficient integrity.

One important scenario in a laser lab is when there may be capability for multiple laser wavelengths to be present, but a single type of eyewear to block all of these wavelengths is impractical (usually because the visible light transmission of the eyewear would be too low to perform the work needed). What is typically done then is to define different Class 4 laser operation modes. Each mode has some wavelength hazards disabled and uses mode-specific LEP to protect only against the accessible wavelengths. In this case, both categories of laser hazard are present: the accessible laser wavelengths and the inaccessible/disabled laser wavelengths. Laser safety programs must ensure effective CoHE controls are used in this situation for the disabled laser wavelength hazards, as well as for the situation where all laser hazards are disabled. It is likely that these controls will utilize machine guards and alternative controls rather than LOTO, invoking the exception in 1910.147 for tasks that are *routine, repetitive and integral to the use of the equipment for production*. However, OSHA 1910.147 must be considered and LOTO must be used if required.

Summary

CoHE should be defined as “Control measures used to protect workers from the unexpected presence of hazardous energy” and apply to all modes of operation: normal, maintenance and service. CoHE controls need to be broader than LOTO and should encompass 3 different approaches: LOTO, alternative energy controls that use machine guards, and administrative lockout or configuration control. When properly administered, LOTO can then be considered more as a useful option for laser workers than as an unnecessary burden.

Laser safety programs need to specifically address CoHE and describe the controls used to provide effective protection when laser hazards are disabled. CoHE controls need to include use of machine guards or energy isolation devices, zero energy verification, written procedures (SOP), and personal control (e.g. training, especially OJT). Special attention needs to be given for operation modes which have some laser wavelength hazards disabled, while others are enabled.

The OSHA CoHE (lockout/tagout) regulation 1910.147 applies to Class 3B and Class 4 laser radiation because of the potential for an eye injury, and compliance with it must be addressed in laser safety programs. It is often ignored by the laser community, though, for incorrect reasons. This regulation describes useful principles that are important for laser safety: energy isolation devices, zero energy verification, personal control, and written lockout procedures. However, the regulation is focused almost completely on when and how to perform LOTO. It was developed without consideration for applicability to lasers, and as a result can be awkward to apply to lasers. The regulation should be updated to include more consideration for “alternative energy controls,” as described in ANSI Z244.1, with a corresponding description of risk assessment and use of the controls hierarchy.

ANSI Z136.1 should be updated to explicitly describe CoHE principles and requirements (such as zero energy verification) to provide effective protection when laser hazards are disabled. The CoHE descriptions in OSHA 1910.147 and ANSI Z244.1 should be reviewed to help determine what is appropriate for Z136.1.

References

- [1] M. Woods, *Compliance of SLAC's Laser Safety Program with the SLAC Control of Hazardous Energy (CoHE) Program*, SLAC-PUB-13495, January 2009; <http://slac.stanford.edu/pubs/slacpubs/13250/slac-pub-13495.pdf>. Examples of injury incidents resulting from the mistaken belief a laser hazard was disabled can be found in two incidents reported in the 2005 DOE Special Operations Report on Laser Safety, http://www.hss.energy.gov/csa/analysis/reports/Laser_Safety_Report.pdf, and in a 2011 hand injury described in a DOE ORPS report linked from http://www.efcog.org/wg/esh_ls/laser_orps_reports.htm. A recent example of a near miss event (no injury) that also resulted from the mistaken belief a laser hazard was disabled is described in a SLAC 2011 Lessons Learned report linked from http://www.efcog.org/wg/esh_ls/documents.htm.
- [2] The OSHA-LIA alliance webpage is <http://www.osha.gov/dcsp/alliances/lia/lia.html>. (LIA is Laser Institute of America, which is responsible for ANSI Z136.1.)
- [3] 29CFR1910.147, OSHA regulation for *The control of hazardous energy (lockout/tagout)*, http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9804.
- [4] OSHA Regulation 29CFR1910 Subpart O, *Machinery and Machine Guarding*, http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10131. This includes OSHA Regulations 29CFR1910.211-219, which are linked from http://www.osha.gov/pls/oshaweb/owasrch.search_for_m?p_doc_type=STANDARDS&p_toc_level=1&p_key_value=1910.
- [5] DOE 10CFR851 Rule, *Worker Safety and Health Program*, <http://www.hss.energy.gov/healthsafety/WSHP/rule851/rule.pdf>.
- [6] ANSI/ASSE Z244.1 -2003 (R2008), American National Standard for *Control of Hazardous Energy -- Lockout/Tagout and Alternative Methods*.
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- [10] ANSI Z136.1-2007, American National Standard for *Safe Use of Lasers*.
- [11] CDRH 21CFR1040.10, *Performance standards for Laser Products*, <http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcr/cfrsearch.cfm?fr=1040.10>.

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